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The accuracy of 'haptically' measured geographical slant perception

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ABSTRACT

In two recent issues of Acta, the widely accepted view of Proffitt (2006), that 'haptic' measures of perceived geographical slant are generally accurate, and dissociated from explicit overestimates, came under intense scrutiny (Durgin, Hajnal, Li, Tonge, and Stigliani, 2010; 2011). Durgin and colleagues' challenge to this account centred on the claim that Proffitt's haptic' measure of geographical slant, the palm-board, may be accidently accurate due to restricted movements available at the wrist. Two experiments reported here compare the accuracy of Proffitt's palm-board with an alternative measure of geographical slant perception, the Palm-Controlled Inclinometer (PCI), which allows participants to use wrist, elbow and shoulder movements to match slant with their hand. Participants (N = 320) made slant judgements using both measures, across five hills and five staircases with 32 participants for each stimulus angle (4.5°–31°). Results for the palm-board replicated those of Proffitt and co-workers, overestimation at shallow angles (≤14°), contrasted with underestimation at steeper angles (≥23°), whereas estimates made using the PCI had a greater degree of accuracy for steeper slopes. A follow-up experiment tested the accuracy of the palm-board and PCI for surfaces in near space to repeat the design of Durgin et al. (2010, experiment 1). Participants (N = 20) used the palm-board and PCI to judge the angle of slanted blocks (25°, 30°). As with traversable slopes, PCI judgements did not differ from the actual angle of the blocks whereas the palm-board measure underestimated. 'Haptic' measures of geographical slant perception can be accurate for relatively steep slopes, in both near and far space.

1. Introduction

When standing at the base of a hill, our visual perception of its steepness is exaggerated. The first formal exploration of the apparent steepness of hills, termed geographical slant perception, concluded that while our explicit awareness of hill slant is prone to overestimation, when using a 'haptic' measure, we are more accurate at judging a hill's incline (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). The measure developed to test 'haptic' perception of hill slant was the palm-board (Fig. 1). Participants place their palm on the board and, without looking at their hand, tilt back the board to match the slant of the hill. This device is still actively being used in geographical slant research with no apparent changes to its design (e.g. Riener, Stefanucci, Proffitt, & Clore, 2011). Throughout this paper, the descriptor that Proffitt et al. (1995) used for these palm-board measures, 'haptic', is retained for comparability with previous studies despite its more common connotation with touch.

Since Proffitt and co-workers' initial research into geographical slant perception, subsequent studies which have used the palm-board consistently suggest that it provides a more accurate measure of the actual slant of real-world stimuli than measures Proffitt links to explicit awareness, such as verbal reports and visual matching. Furthermore, studies have shown that 'haptic' estimates with the palm-board are unaffected by changes in behavioural potential. For example, when participants were encumbered by a heavy backpack, or sent on exhausting runs, their verbal reports and visually matched estimates of hill slant increased (Bhalla & Proffitt, 1999). Palm-board estimates on the other hand, showed no effects of either manipulation. Subsequent studies reveal the same pattern of results. While verbal and visual judgements respond to manipulations of energy resources (Schnall, Zadra, & Proffitt, 2010), psychosocial resources (Schnall, Harber, Stefanucci, & Proffitt, 2008), fear (Stefanucci, Proffitt, Clore, & Parekh, 2008), and mood (Riener et al., 2011), judgements made using the palm-board are unaltered, suggesting that a more stable process is used for 'haptic' judgement of geographical slant.

Researchers unaffiliated with Proffitt's group have also reported generally accurate estimates when using similar measures to the palm-board. For example, participants in a series of experiments by Feresin and Agostini (2007) adjusted a paddle board with their hand to estimate the slant of urban roads. In both the natural environment and a laboratory setting, judgements did not differ from the physical slant of the roads when stimuli were viewed from less than 4 m away. Furthermore, in a study that predates Proffitt's work on geographical slant, Kinsella-Shaw, Shaw, and Turvey (1992) showed that participants were generally accurate at judging the slant of walkable surfaces when adjusting an unseen foot ramp to match the slope.

What had not been brought into question until recently was Proffitt's suggestion that using a palm-board to match a hill's slope

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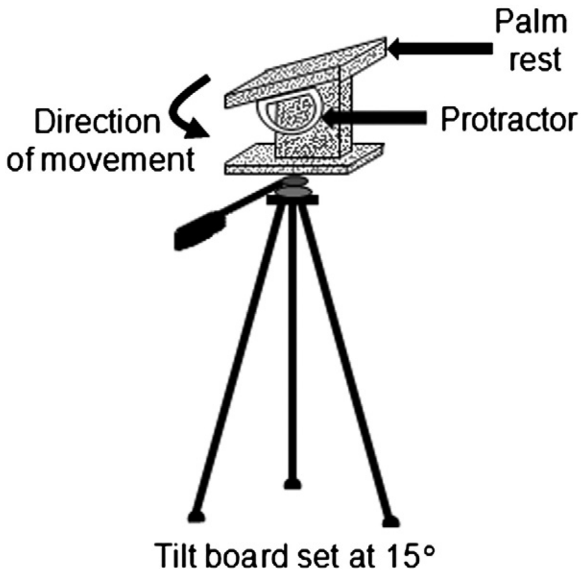

Fig. 1. A depiction of Proffitt's palm-board measure traced from Proffitt et al. (1995).

was a visually guided motor action. A series of experiments presented by Durgin et al. (2010) concluded that Proffitt's palm-board measure was "biased and variable due to poorly calibrated proprioception of wrist flexion" (p. 182). Durgin et al. (2010) argue that adjusting a palm-board makes use of only one degree of freedom, the wrist joint, which has a restricted range of motion. They suggest that the resulting judgements of slant made with a palm-board are actually underestimates of proprioception, and "accidently accurate" (p. 185, Durgin et al., 2010). In their first experiment, Durgin et al.'s participants (N = 25) made adjustments with a free-hand or a palm-board to match a slanted wooden block (30°) positioned on a table in front of them. Results showed that participants could reproduce the block's incline with a free-hand reasonably accurately (32.7°), but reliably underestimated when using the palm-board (19.4°). In their second experiment, Durgin et al. (2010) used a real hill (24.5° when looking straight ahead) as the stimulus, measuring verbal reports in degrees, matching with a free-hand, and 'haptic' matching using a palm-board. Verbal reports and free-hand matching estimates reliably overestimated the actual slant of the hill (+19.8° and +11.6° respectively), while those made with a palm-board reliably underestimated the hill's incline (−6.4°). Durgin et al. (2010) argued that if free-hand matching, with unrestricted proprioceptive cues, was subject to overestimation, then so should 'haptic' matching using the palm-board. They argued that palm-boards simply did not allow enough range of movement in order to reveal this overestimation. In reply, Proffitt and Zadra (2011) argued that the results with wooden blocks do not generalise to studies on geographical slant where the surface affords climbing, and questioned the accuracy of the palm-board measures of Durgin and colleagues.

While Proffitt's (2006) summary of his model of geographical slant perception suggests that 'haptic' judgements should not differ from the actual slant of the stimulus, the original normative data from Proffitt et al. (1995) reveal a different picture (see also Proffitt & Zadra, 2011). The 'haptic' measures differed from the actual slant in three out of four studies, though "the magnitudes of these differences were quite small when compared with the verbal and visual measures" (page 425; Proffitt et al., 1995). When judging real hills from their base with the palm-board, participants overestimated for angles ≤10°, were accurate for the 21° and 31° hills and underestimated the slant of the steepest hill tested, namely 34°. In the studies presented by Durgin et al. (2010), however, average palm-board judgements reliably underestimated the stimuli throughout. This discrepancy led Proffitt and Zadra (2011) to raise concerns about the apparatus used in Durgin et al.'s experiments, suggesting that the palm-board might have been more difficult to adjust than Proffitt and co-workers' palm-boards.

Given the nature of the argument between Proffitt and Durgin's groups, new 'haptic' data for the study of geographical slant perception should be informative. Coincidently, during the period over which this debate was taking place, a new measure of geographical slant perception was being developed by an independent research group. This device, the 'Palm-Controlled Inclinometer' (PCI), forms a key measure in a programme of research investigating pedestrians' perceptions of the real-world stimuli of public access staircases, which are typically between 20° and 30° in slant angle. Like Durgin and co-workers, we were concerned that restriction of movement around the wrist joint may influence palm-board estimates for the relatively steep stimuli characteristic of stairs in the built environment. The PCI was designed to allow participants freedom of movement around the wrist, elbow and shoulder joints when judging slopes.

In this report, we first present results of a methodological study which compared estimates of the PCI to a replica of Proffitt's palm-board measure across a range of sloped real-world stimuli. The first study tested whether comparable estimates were obtained with both measures in the field. Further, in a follow-up experiment we replicate Durgin et al.'s (2010) experiment 1 for blocks in near space but replace their free-hand measure with the PCI.

2. Experiment 1

2.1. Methods

To compare estimates of geographical slant between the PCI and palm-board, we used a within-subject comparison whereby participants judged the slant of a real hill or staircase on each of the two measures in a counterbalanced order.

2.1.1. Participants

Members of the University of Birmingham community (N = 320, M = 23.22 years, SD = 7.06 years) were recruited "to help calibrate some equipment" as they passed by the experimenter at a given hill or staircase. Measurement order and participant gender remained balanced throughout, with 32 participants being tested on each slope.

2.1.2. Apparatus

2.1.2.1. Palm-Controlled Inclinometer (PCI). The PCI, depicted in Fig. 2, is a new measure of geographical slant perception, designed with particularly steep slope stimuli in mind. To judge slant with the PCI, participants place their hand on a plate that forms the base of an underslung pendulum and push it forward until they feel as though their palm is in line with the slope of the stimulus in front of them. This action of pushing the pendulum forward makes use of muscles around the wrist, elbow and shoulder joints simultaneously.

The angle to which the bottom plate of the pendulum is set is measured electronically using a linear potentiometer attached to the pivot of the pendulum. As the pendulum swings, the attached potentiometer turns. A regulated voltage is applied across the potentiometer and the voltage present on the wiper of the potentiometer is zeroed and amplified. The gain of the amplifier is calibrated to report inclination in degrees to one decimal place on an LCD voltmeter attached to the side of the apparatus, outside the view of participants. The PCI has a maximum range of motion of 63°. Due to the use of an underslung pendulum the plate returns to the horizontal when the hand is removed. Full dimensions of the box and swing components of the PCI can be found in the supplementary materials.